THE ORIGIN OF OLIVINE IN MARTIAN METEORITE ALH 84001. THE DISTRIBUTION OF OLIVINE. Shearer, C.K. and Adcock, C.T., Institute of Meteoritics, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131-1126.

INTRODUCTION: Although olivine was not identified in the original description of ALH 84001 [1], irregular-shaped olivine inclusions in orthopyroxene were recognized by Harvey and McSween [2]. The origin of these olivine inclusions is controversial and may shed light on the temperature of origin for the "hydrothermal" system that deposited carbonates in the fractures in ALH 84001. The temperature of carbonate formation has profound implications for these carbonates recording early biogenic activity on Mars [3]. Two irreconcilable petrogenetic models have been proposed for the origin of the olivine inclusions. Harvey and McSween [2] proposed that the textural relationship between the orthopyroxene and olivine may have been produced by high temperature interaction with a CO_2-rich fluid. This reaction(s) would have also produced the magnesite in ALH84001 at temperatures greater than 525°C. Under this scenario, the observations and conclusions made by McKay et al. [3] would be incorrect. On the other hand, Treiman [4] pointed out that that the compositions of the silicates and oxide minerals are not consistent with such a high temperature reaction.. This interpretation [4] implies that the olivine inclusions are magmatic in origin [2,4] and therefore do not constrain the temperature of the hydrothermal system. Our approach to deciphering the origin of the olivine in ALH 84001 is two fold. First, as reported in this abstract, we mapped the distribution of olivine inclusions in ALH 84001. Our observations indicate that the olivine inclusions are not randomly dispersed within the orthopyroxene. They are, in fact, closely associated with fractures filled with high-K shock glass [1,6]. Second, as reported in a companion abstract [5], we measured the oxygen isotopic characteristics of the olivine.

METHOD: The distribution, morphology, and composition of olivine was determined in two thin sections of ALH84001: ,83 and ,87. We used a JOEL 733 Superprobe electron microprobe (EMP) equipped with an Oxford LINK eXL II analyzer. The user interface includes an image analysis package called Featurescan. We configured Featurescan to detect and measure olivine. Features in the field of view that meet both size and backscattered electron intensity criteria are then analyzed by energy dispersive spectroscopy (EDS) to determine if they meet the general chemical criteria to be olivine. The contrast in backscattered electron intensities between olivine and orthopyroxene is well illustrated in Figure 1. If a feature meets all the criteria, the position of the feature in the field of view as well as the position of the field of view on the sample are written to a file and the features are revisited later and analyzed with more accurate wavelength dispersive spectroscopy (WDS). The ability of the Oxford interface and Featurescan to create grids of fields of view and drive the EMP stage allows analyses to be carried over the area of the entire thin section in a period of 6 to 8 hours. Over 1000 fields of view were analyzed for each thin section.

DISTRIBUTION, MORPHOLOGY, AND COMPOSITION OF THE OLIVINE INCLUSIONS: Over 60 olivine inclusions in orthopyroxene were identified in thin sections ALH 84001,83 and ,87. Far more were found in the thin section with more abundant carbonate and "plagioclase" glass (ALH 84001,83). The olivine inclusions are irregular in shape (Figures 1,2,3) and range in size from approximately 40µm to less than 1µm. Some of the inclusions are elongate and "boudinage-like" (Figure 3). The inclusions are in sharp contact with the enclosing orthopyroxene, and often contain small inclusions of chromite. The chromite is of similar composition as that found outside the olivine [1]. The olivine exhibits a very limited range of composition from Fo_{65} to Fo_{66} (n= 25). This overlaps with the composition reported by Harvey and McSween [2]. Orthopyroxene that is adjacent to the olivine is more magnesian than the olivine with an average composition of En_{70} Fs_{27} Wo_3 . In the two thin sections studied, the olivine does not occurs randomly as perhaps would be expected if they were simple inclusions within the orthopyroxene. Rather, the olivine occurs as "clusters" within a limited number of textural settings associated with fractures. Many of the olivine inclusions occur in orthopyroxene adjacent to fractures containing disrupted carbonate globules [7, 8] and high-K plagioclase glass [6]. A most intriguing element of this texture is that the olivine occurs in the orthopyroxene at the base of the carbonate globules (Figure 1). The olivine inclusions are also spatially associated with fractures that contain only the high-K plagioclase glass. Whether the carbonate globules do not occur in these fractures or are just not present in this thin section slice through the fracture is not known.

CONCLUSIONS: Based on the observation, that the irregular-shaped olivine inclusions are not randomly distributed within the orthopyroxene, but spatially associated with specific fractures, it seems unlikely that they simply represent trapped magmatic olivine. More likely, the textures indicate that either (1) the olivines were magmatic inclusions in the orthopyroxene that were remobilized and realigned during the shock-event(s) or (2) that they represent a reaction between the shock glass and orthopyroxene which resulted in a loss of Si to the glass component. It appears unlikely that the olivine is produced during carbonate-forming reactions. Mineral geothermometers using olivine and associated phases record a high temperature, subsolidus environment. Fe-Mg distribution between olivine and chromite inclusions in the olivine and between Ca-free olivines and orthopyroxene yield temperatures of between 800 to 900°C [9,10]. An oxygen isotopic study in a companion abstract [5] confirms that the olivine was not involved in carbonate-forming reactions and is a high temperature phase.

REFERENCES: [1] Mittlefehldt (1994) *Meteoritics* 29, 214. [2] Harvey and McSween (1994) *Meteoritics* 29, 472. [3] McKay et al. (1996) *Science* 273, 924. [4] Treiman (1997) *LPSC XXVIII*, 1445. [5] Shearer and Leshin (1998) *LPSC XXIX* in press. [6] Shearer et al. (1998) *LPSC XXIX* in press. [7] Shearer and Adcock (1998) *LPSC XXIX* in press. [8] Shearer and Adcock (1998) *Nature* in review. [9] Sack and Ghiorso (1991) Am. Mineral. 76, 827. [10] Sack and Ghiorso (1989) Contrib. Mineral. Pet. 102, 41.

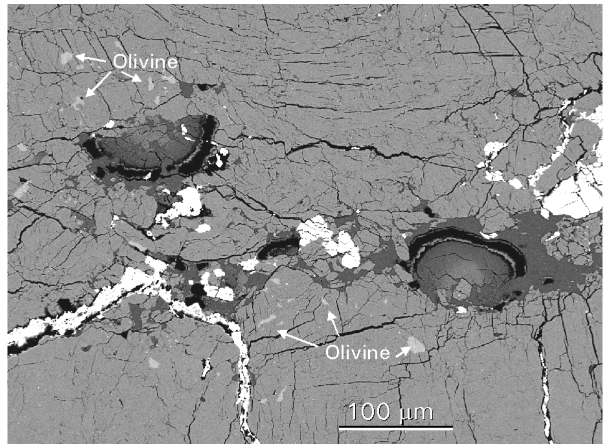

Figure 1. BSE image of a series of fractures in ALH 84001,83. Orthopyroxene makes up a majority of the field of view (≈ 650µm across). Olivine is the lighter colored patches in the orthopyroxene adjacent to the base of the carbonate globules.

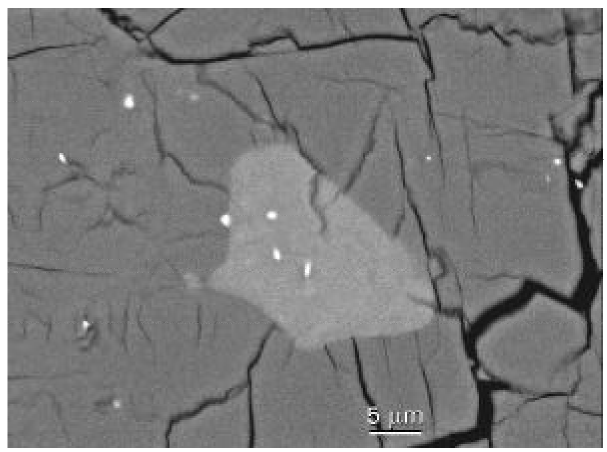

Figure 2. Olivine inclusion in the orthopyroxene.

Figure 3. Elongate olivine inclusion in the orthopyroxene.